



Zero Emission Coal to Hydrogen

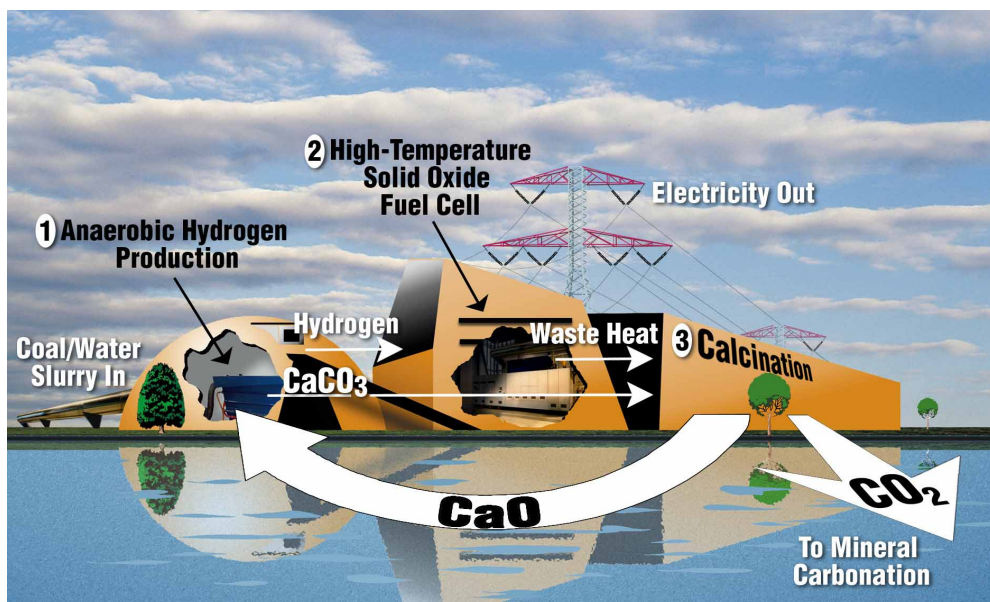
Advantages

- Extremely high conversion efficiency from fuel energy to electrical energy
- “Waste” heat recycled
- Compared to conventional power plants:
 - More than twice as much electrical energy/unit of fuel
 - Less than 1/2 the CO₂ production/kilowatt-hour
 - Simultaneous production of a pure CO₂ waste stream
 - No combustion involved
 - No oxygen separation unit needed
 - Inputs required are only coal, water, and continuously recycled calcium oxide

The high standard of living in developed countries depends upon the availability of abundant and inexpensive energy. Eighty-five percent of the world’s energy is still produced from fossil fuels, and the economic stability of many nations, including the US, will depend upon the continued use of fossil fuels well into the next century. However, rising population and more countries aspiring to the US lifestyle could cause carbon dioxide emissions in the next century to exceed all current carbon in the air, all organic carbon in plants and soils, and the ocean’s capacity to absorb CO₂. To prevent such a crisis, Los Alamos National Laboratory is supporting the Department of Energy’s “Vision 21” program which aims to eliminate the environmental concerns associated with the use of fossil fuels for producing electricity.

One technology Los Alamos is developing to achieve this goal is a zero emission process for converting a coal and water slurry into hydrogen, which is in turn converted to electricity via a high-temperature solid-oxide fuel cell. Hydrogen gas is produced from water and coal using a calcium oxide (CaO) to calcium carbonate (CaCO₃) intermediary reaction. Through a subsequent reaction, the calcium carbonate generated by hydrogen production is converted back into calcium oxide and a pressurized stream of pure CO₂. The calcium oxide is recycled to drive further hydrogen production, and the CO₂ stream is ready for easy disposal. High conversion efficiencies (~50%) for electricity generation can be achieved using solid-oxide fuel cells; the ~50% of “waste” heat produced by the fuel cells is not truly wasted because it is reinjected into the process to drive the calcination

A zero emission power plant for a sustainable future. Pure hydrogen is produced anaerobically (1) and converted to electricity via a solid-oxide fuel cell (2). Calcium carbonate from the initial reaction and waste heat from the fuel cell are used to recycle calcium oxide for further hydrogen production and to remove pure CO₂ in a concentrated stream that can be disposed of through mineral carbonation (3).



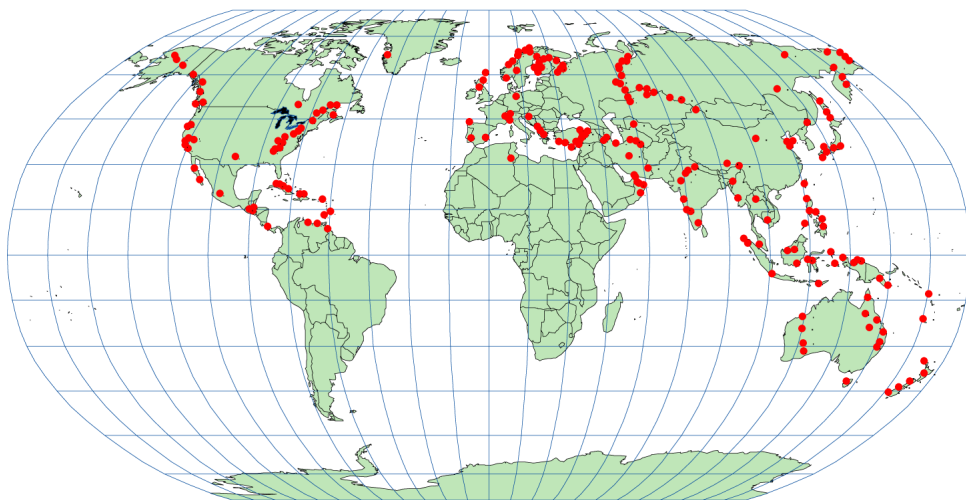
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reaction. The process is anaerobic, requiring no oxygen input or combustion, which eliminates the need for the costly oxygen separation systems found in many gasification plants. The absence of oxygen also reduces nitrogen oxide by-products to only those resulting from nitrogen compounds in the coal itself.

While coal is the current focus, this process can be adapted to run on any fossil fuel and even biomass. Compared to conventional power plants, this new system generates at least twice as much electrical energy per unit of fuel consumed and produces less than half the CO₂ waste per kilowatt hour generated.

Mineral Carbonation: Permanent Disposal of CO₂ Waste

To ensure that the process is environmentally benign from start to finish, Los Alamos is also developing viable options for sequestering the CO₂ waste produced by fossil fuels. One of the most promising options is mineral carbonation, through which the already pressurized CO₂ stream is reacted with magnesium or calcium silicate mineral deposits to form geologically stable mineral carbonates. The reaction, which is merely accelerated through technology, is part of the natural geological carbon cycle; therefore, all mineral end products are naturally occurring and completely benign. Rather than temporary storage, mineral carbonation offers permanent fixation of CO₂ thereby eliminating legacy issues for future generations. The mineral sequestration process is economically viable because the CO₂ stream is non-mechanically pressurized in the hydrogen production process and the carbonation reaction is exothermic (i.e., it creates energy instead of consuming it). In addition, the types of mineral deposits needed to carry out the reaction are abundant enough to handle all the carbon associated with the world's coal reserves.



Magnesium-rich ultramafic rocks, primarily peridotites and serpentinites, are the main candidates for mineral carbonation. The map above indicates the abundance and wide distribution of ultramafic deposits (in red) throughout the world (deposits smaller than 1 km³ are not included).

Los Alamos National Laboratory always seeks partners and sponsors to help develop its technological innovations. To learn how to collaborate with the Laboratory in developing this technology and others, contact the Energy and Sustainable Systems Program Office.

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